ABSTRACTS

Ammonia Summit

Assessing the Role of Ammonia/um in the Delta and Suisun Bay Ecosystem

A Public Interagency Ecological Program (IEP) Workshop

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Central Valley Regional Water Quality Control Board
11020 Sun Center Drive, #200
Rancho Cordova, CA 95670

Wilkerson, F.P.
Romberg Tiburon Center, San Francisco State University

Is There Suppression of Algal Production in Suisun Bay?

Data collected in the northern estuary from 1999 to 2003 showed that the relative concentrations of ammonium and nitrate to the DIN pool could modulate the phytoplankton productivity. At this time there was also recognition of the Pelagic Organism Decline (POD) that was thought to be caused in part by bottom up food web effects linked to low levels of phytoplankton (chlorophyll). As a result, CALFED funded a project by Dugdale, Wilkerson, and Parker that was started in spring 2007 (and stopped prematurely with a stop work order in December 2008) to study the anomalous low phytoplankton productivity in Suisun Bay. The goal was to compare Suisun Bay phytoplankton growth and nutrient uptake rates with those in Central San Francisco Bay. In addition, phytoplankton performance was also measured at Rio Vista, upstream in the Sacramento River with the original view that Suisun was somehow "bad" as had been identified by the IEP POD Working Group. In addition to characterizing the water at these three sites, experimental "grow-outs" were used as a simple tool to evaluate the physiological response of the phytoplankton when provided optimal conditions. The data from these grow outs show that both Suisun and Rio Vista consistently have suppressed phytoplankton production and nutrient drawdown capabilities compared to Central Bay communities, although Susiun can accumulate chlorophyll and appears less suppressed than the Rio Vista communities. The term f, the percent nitrate uptake used for phytoplankton growth, can be applied to characterize the different systems and show Suisun and Rio Vista (and the rivers) to have low values compared to Central Bay, both in the field and in grow-outs. Interestingly in grow outs, with improved light conditions and time, the river phytoplankton can increase the f and use nitrate and accumulate chlorophyll. Ambient ammonium appears to suppress nitrate uptake and primary production and extends the time for blooms to occur. Ammonium comes from local recycling, agricultural runoff, and the discharge from wastewater treatment plants (WWTPs). The principal exogenous source appears to be WWTPs, which at least in principle can be reduced. Therefore, if this potential mechanism for phytoplankton production suppression bears out as an important contributor to low food web production, it may suggest a management tool for increasing production.

Parker, A.E.
Romberg Tiburon Center, San Francisco State University

Effect of Wastewater Treatment Plant Effluent on Algal Productivity in the Sacramento River Part 1: Grow Out and Wastewater Effluent Addition Experiments

Two experimental approaches were employed to more directly observe the potential impact of wastewater effluent and elevated NH_4 on primary production and nitrogen uptake by phytoplankton isolated from the Sacramento River. The first approach relied on 20-L enclosures filled with river water at locations upstream and downstream of SRWTP and incubated over 7 to 10 days, in order to characterize the potential timing and magnitude of nutrient drawdown and phytoplankton blooms under different wastewater effluent and NH_4 concentrations. The second approach, modeled after a published study conducted at a coastal sewage outfall in southern California, was to make serial enrichments of either wastewater effluent or NH_4Cl (0 - 100µM N) to incubation bottles in order to make primary production and phytoplankton N uptake (as NH_4 or NO_3) estimates over 6-hr. Results from enclosure experiments show that when provided with high light and isolated from circulation effects, river phytoplankton have the potential to exhaust nutrients and build chlorophyll-a both at locations above and below the SRWTP. This finding is in agreement with similar experiments made in Suisun Bay, but in contrast to results obtained farther downstream at Rio Vista, where phytoplankton were unable to utilize nutrients or build chl-a. During serial addition experiments both effluent and NH_4Cl additions inhibited phytoplankton NO_3 uptake; strongly NO3 inhibition was observed at relatively low (~1 µM) NH_4 concentrations. Inhibition of phytoplankton C uptake was observed in treatments with elevated wastewater NH_4 but not elevated NH_4Cl concentrations. This suggests that some component of wastewater effluent, other NH_4, may inhibit phytoplankton C production and inhibit biomass accumulated.

Parker, A.E.
Romberg Tiburon Center, San Francisco State University

Effect of Wastewater Treatment Plant Effluent on Algal Productivity in the Sacramento River Part 2: Transect Results

Elevated ammonium (NH_4) concentrations have been shown to reduce primary production and limit phytoplankton blooms along the salinity gradient of the northern San Francisco Estuary (SFE). The major source of freshwater to the Sacramento-San Joaquin Delta is the Sacramento River which receives wastewater effluent from the Sacramento Regional Wastewater Treatment Plant (SRWTP) resulting in ambient ammonium concentrations in the river that are 5 to10-fold greater than in the northern estuary. This has led to the hypothesis that NH_4 from the SRWTP may limit primary production in the Sacramento River and contribute to reduced primary production in the northern SFE. Five transects of the Sacramento River in the vicinity of the SRWTP were completed during 2008/2009 to determine the distribution of macronutrient concentrations, characterize the phytoplankton community and estimate primary production. The principle findings were that macronutrient concentrations (especially NH_4) were highly variable in the Sacramento River but stations downstream of SRWTP consistently had elevated NH_4 and PO_4 concentrations as much as 100-fold higher than at stations upstream of the wastewater treatment plant. Chlorophyll-a concentrations showed consistent declines from stations upstream of SRWTP to station downstream - Primary production, already very low by most standards, expressed as carbon fixation, also declined from stations upstream of SRWTP to stations downstream. Phytoplankton N uptake rates declined at stations downstream where NO_3 uptake was suppressed by ambient NH_4 concentrations and phytoplankton were using NH_4 to support N demand.

Dugdale, R.C.
Romberg Tiburon Center, San Francisco State University

Transport of Nutrients from Sacramento River to Suisun and Grizzly Bays: Effects on River and Bay Chlorophyll Concentrations

Our recent measurements of nitrate (NO_3) and ammonium (NH_4) uptake rates by phytoplankton in the Sacramento River allow a comparison with previously published rates for the San Francisco Estuary from Central Bay to Suisun Bay. The rates for the river are low and consistent with those for Suisun Bay. The injection of NH_4 at RM44 by Sacramento Regional WWTP shuts off the access of phytoplankton to ambient NO_3, a result in accordance with previous work in the lower estuary. The river can now be separated into distinct regions, the "Upper River" (above RM44 to I80) where phytoplankton use both NH_4 and NO_3 for growth and "Lower River" below RM44where phytoplankton grow only on NH_4 and with lower primary production rates such that there are declining phytoplankton concentrations downstream. There may also be consequences for the species of phytoplankton produced in the NH_4 only regime in the Lower River, e.g. the production of *Microcystis* sp blooms.

The capacity of the Lower River to absorb the effluent source of NH_4 introduced at RM44 can now be evaluated with data. First, the euphotic zone-depth integrated NH_4 uptake measurements were calculated using uptake versus light factors from prior experiments with Central Bay water incubated with decreasing light (i.e. a proxy for increasing depth). The result of the low euphotic zone NH_4 uptake rate and shallow euphotic depth in the Lower River (1.3m with a Secchi depth of 0.5m), then mix in to the complete water column depth (~ 8m at RM44) such that this low uptake level is diluted about 80%. The river condition is a classical example of the Sverdrup "Critical Depth" effect; no biomass accumulation could be expected when the mixing depth (8m) is deeper than the euphotic zone depth (1.3m). A simple box model using the measured NH_4 uptake rates predicts that only at low flow conditions and NH_4 concentrations below 1 µM (0.014 mg/L) will bloom conditions occur and produce high chlorophyll concentrations within the river. At intermediate flow rates, i.e. in the range of about 400-600 m^3/s, a small increase of initial NH_4 concentration from 1 to 2 µM results in a 75% decrease in chlorophyll concentration, to a low production regime. When the correction for mixed layer depth (80% dilution of uptake) is applied, the net uptake of river NH_4 is calculated to be about 1% of the river water column NH_4 per day. The observed declining pattern of NH_4 concentration downstream of RM44 is virtually unaffected by phytoplankton activity. Whatever NH_4 that is introduced at RM44 will appear downstream at the entrance to Suisun Bay, evidently modified by other processes, e.g. nitrification (NH_4 oxidation), denitrification (reduction to N_2) or by other inputs. In the absence of these other processes, NH_4 concentrations in the river, if they reach or exceed 1 or 4 µM will end up affecting the Suisun Bay ecosystem. Inputs of NH_4 sufficient to bring the river concentration to either 1 or 4 µM will be imposed on Suisun Bay ecosystem processes.

Mioni, C.E., A. Paytan
University of California, Santa Cruz

Does Ammonia Impact the Distribution of Harmful Algae and Phytotoxins in the San Francisco Estuary?

Harmful algae (HA) are some of the less studied Bay and Delta species and their distribution, abundance as well as the conditions promoting their proliferation are not well characterized. Accurate monitoring of HA and associated toxins is needed to establish a baseline for future comparison and to predict changes associated with climate change and anthropogenic impacts. Such information is crucial for mitigating future impacts of HA blooms (HAB) on water quality, considering predicted future environmental changes in temperature, stratification, nutrients and trace metals loading that can potentially alter the HA abundance and toxin production.

To successfully allow early HAB detection and to design best management and preservation plans, we have adopted an adaptative monitoring strategy. Monitored variables include distribution of HA (cyanobacteria, diatoms, dinoflagellates) and their toxins (microcystins, domoic acid and saxitoxin) in the San Francisco Estuary as well as suspected environmental stressors, including ammonium.

Here, we will present preliminary results from monthly monitoring throughout the Bay and the Delta including spatial and temporal distribution of algae and toxins (domoic acid, saxitoxins, microcystins) in relation to ammonium concentrations.

Lehman, P.W.
CA Department of Water Resources, Division of Environmental Services

Microcystis and nutrients in San Francisco Estuary

The factors that caused the appearance and increase of the toxic cyanobacterium *Microcystis aeruginosa* (*Microcystis*) in San Francisco Estuary since 1999 are unknown. It is hypothesized that coincident increases in ammonium load from wastewater treatment facilities in the western portion of the estuary may have contributed to development of this cyanobacterium harmful algal bloom (CHAB) during the summer and fall each year. To test this hypothesis, nutrient bioassay studies were conducted monthly between June and September 2008 at a brackish water station Antioch and a freshwater station Mildred Island. Two levels of ambient nutrient concentrations were tested, undiluted ambient water (100% dilution) and ambient water diluted by 50% with water matching the ionic composition at each station (50% dilution). Varying low levels of nitrate, ammonium, soluble phosphorus and nitrate plus soluble phosphorus at 1 to 8 times ambient concentration were added to 4 L cubitainers containing 100% or 50% ambient nutrient concentrations and incubated in situ for 5 days at 50% ambient light. Chlorophyll *a* concentration and nutrient concentrations were measured daily while *Microcystis* abundance was measured on alternate days. Initial nitrogen to phosphorus molar ratios were either near or below the Redfield ratio (11 to 19). Results were similar for both the freshwater and brackish water stations. After 5 days of incubation, chlorophyll *a* concentration was usually not significantly different among treatments within months, except for nitrate and ammonium in September. Over all months, nitrate treatments had significantly greater ($p<0.05$) chlorophyll *a* concentration than soluble phosphorus treatments. Preliminary data indicate *Microcystis* abundance was highly variable among treatments and was not significantly different in nitrate and ammonium treatments compared with the control during the initial phase of the bloom in June or peak of the bloom in August for Antioch.

Teh, S.J.
UC Davis, Aquatic Toxicology Program

Acute Toxicity of Ammonia, Copper, and Pesticides to Key Copepods, Pseudodiaptomus forbesi and Eurytemora affinis, of the San Francisco Estuary (SFE)

Toxicity testing (96-h) of ambient surface waters from several locations in the North and South Delta in April-May 2008 was shown to significantly affect the survival of *Eurytemora affinis.* The sensitivity of *Pseudodiaptomus forbesi* to ambient waters of the SFE is unknown; however, this species is more sensitive to *Microcystis* compared to *E. affinis* as observed in previous studies in our laboratory. Although chemical contaminants such as ammonia, bifenthrin, copper, diuron, lambda cyhalothrin, and polyaromatic hydrocarbons have been detected in ambient waters, the impacts of these contaminants to pelagic organisms in the SFE food web are critically unknown. The sensitivity of dominant zooplankton in the estuary, particularly *E. affinis* and *P. forbesi*, to these contaminants is unknown including the potential effects of ammonia and other factors associated with differences in toxicity levels between the species. The objectives of this study were to: 1) determine the acute toxicity of ammonia, bifenthrin, copper and permethrin to *E. affinis* and, 2) compare the sensitivity of *E. affinis* and *P. forbesi* to ammonia at various pH levels under constant temperature and salinity. In *E. affinis*, the 96-h LC50 at pH 8.1 was 10.97 mg/L total ammonia or 0.78 mg/L unionized ammonia, 0.013 µg/L bifenthrin, 3.48 µg/L copper, and 0.158 µg/L permethrin; acute toxicity (96-h LC50 at pH 7.6) to total ammonia was 7.56 mg/L or 0.12 mg/L unionized ammonia. For *P. forbesi*, 72-h LC50 was at 7.68 mg/L total ammonia or 0.12 mg/L unionized ammonia; acute toxicity (96-h LC50 at pH 7.6) to ammonia was not determined because this species did not survive exposure to ≥10 mg/L ammonia concentration. Additional studies are in progress to determine the effects of pH and ammonia to both zooplankton species. Current findings indicated that *E. affinis* were more sensitive to ammonia, bifenthrin, copper, and permethrin than most Delta fish and invertebrates tested. That *P. forbesi* were more sensitive to ammonia compared to *E. affinis* suggest the potential effects of ambient unionized ammonia levels to the growth and reproduction of these copepods in the Delta. It is likely that the toxicities observed in *E. affinis* in 2008 may have been associated with the presence of one or combined effects of these chemicals in the ambient water.

Werner, I.
UC Davis, Aquatic Toxicology Laboratory

Effects of Ammonia/um and Other Wastewater Effluent Associated Contaminants on Delta Smelt

Contaminants and their potential deleterious effects to fish in the Sacramento-San Joaquin Delta are of particular interest due to negative long-term population trends and a possible step decline in numbers of several pelagic fish species in the years 2000-2001. This trend, known as the pelagic organism decline (POD), has been the focus of an increasing number of investigations over the past several years, but no single cause has so far been identified. Delta smelt (*Hypomesus transpacificus*) is one of the species of concern in the POD. It is endemic to the Delta and has recently been federally listed as endangered.

Studies were performed by the UC Davis Aquatic Toxicology Laboratory and Central Valley Regional Water Quality Control Board, in collaboration with the Sacramento Regional Wastewater Treatment Plant (SRWTP) and IEP-POD to assess the toxicity of total ammonia and ammonium (ammonia/um), ammonia, and treated wastewater effluent from the Sacramento Regional Wastewater Treatment Plant to larval delta smelt (*Hypomesus transpacificus)*. Experiments were conducted to determine toxic effect concentrations of ammonia/um. In addition, two series of increasing concentrations of total ammonia/um were tested. The two sources of ammonia/um were 1) the SRWTP effluent, and 2) a stock solution of ammonium chloride. Concentrations ranged from 0.25-8 mg/L ammonia/um. The dilution water used for both test series was ambient water collected from the Sacramento River at Garcia Bend upstream of the SRWTP. Garcia Bend water was collected daily, one day prior to being used for testing throughout the 7-d flow-through test. SRWTP effluent in the form of 24-h composite samples was also collected daily. Control treatments for delta smelt consisted of water obtained from the delta smelt culturing facility, unaltered upstream Garcia Bend Sacramento River water and delta smelt culturing facility water adjusted with deionized water to the conductivity of Sacramento River water. Concurrent tests with larval fathead minnow (*Pimephales promelas)* were conducted. Reference toxicant tests were performed for both species to account for differences in organism sensitivity. Test protocol specified that delta smelt survival in controls be at least 60 percent for the test results to be considered acceptable.

No significant effect on 7-d survival was detected in effluent and NH_4Cl treatments at concentrations of ≤2 mg/L ammonia/um, however SRWTP effluent was more toxic than corresponding ammonium-chloride treatments at concentrations ≥4 mg/L. No significant reduction in 7-d survival or growth was detected in larval fathead minnow tests. The bioassay results suggest that ammonia concentrations present in the Sacramento River below the SRWTP are not acutely toxic to 47-55 day old delta smelt, however additional unknown toxicants are present in SRWTP effluent.

Engle, D.
Larry Walker Associates

Total Ammonia and Unionized Ammonia Concentrations in the Delta; an Examination of Ambient Concentrations and Toxicity Thresholds

Abstract – to be provided

Johnson, M.L.
Center for Watershed Sciences, UC Davis

Species Sensitivity Distributions and Exposure Concentrations; Placing Recent Results into Context

Species sensitivity distributions were constructed for acute toxicity of both vertebrates and invertebrates to unionized ammonia. Data sets were obtained from the literature as part of a larger review of the effects of ammonia on aquatic ecosystems, and from recent studies of resident species in the Delta. Because of the extremely large number of studies for some groups of organisms (e.g. salmonids) genus mean acute values (GMAV) for toxicity were calculated and used as the raw data. GMAVs were $\log_{10}$ transformed and standardized, and a cumulative normal distribution was fit to the data. The normal distribution was an acceptable fit to the acute data based on the lack of significance of the Anderson-Darling goodness of fit test. Although GMCVs were developed and SSDs constructed, adequate chronic data are lacking making the fitting of the curves tenuous. The HC_5 values for each distribution were calculated indicating the concentration where 5% of species would be expected to experience acute or chronic effects. The HC_5 values were compared to established criteria which are based on pH, temperature, and the presence/absence of early life stages of fish. The sensitivities of the curves to an individual data point (genus mean acute or chronic values) were calculated indicating that recent test results have a large impact on the shape of the SSDs. The SSD curves were compared to the environmental concentrations (EC) to approximate the number of vertebrate and invertebrate species at risk from acute and chronic effects of unionized ammonia at different time periods and various locations in the Delta.

Fullerton, D.K.
Metropolitan Water District of Southern California

Ammonia Concentrations and the Food Chain in Suisun Bay and the Delta

Abstract – to be provided

Foe[1], C, A. Ballard[1], and R. Dahlgren[2]
[1] Central Valley Regional Water Quality Control Board
[2] Department of Land, Air and Water Resources, UC Davis

Preliminary Ammonia Results from an Ongoing Monitoring Program

A hypothesis is that the pelagic organism decline is being caused, at least in part, by elevated concentrations of ammonia. A nutrient monitoring program was initiated in March 2009 to help evaluate this hypothesis. The program has two parts. First, subsurface grab samples are being taken at 22 locations in the Delta. The water samples were collected twice a month between March and June as this is the time period when larval smelt and salmon, two species that are very sensitive to ammonia, are present in the estuary. Sampling has been monthly since June. The purpose of the multi station sampling effort is to determine whether ammonia concentrations exceed either recommended U.S. EPA chronic criteria to protect sensitive freshwater aquatic organisms or concentrations documented to be toxic to local organisms including freshwater diatoms, delta smelt and salmon. The second part of the program has been an intensive temporal sampling effort (every two hours for two days) at two locations in the Delta: Rio Vista and Antioch. This sampling has occurred on three occasions, March, April and May 2009. The purpose of the temporal sampling is to ascertain whether diurnal and/or tidal nutrient patterns exist in the Delta.

Results of the ongoing monitoring program will be presented with an emphasis on concentrations of nitrogen species in the Sacramento River and Western Delta. A comparison will also be made between ambient ammonia concentrations measured in the monitoring program and both the recommended U.S. EPA chronic criteria and concentrations reported to be toxic to sensitive local organisms.

The results may have value for managers and for the public to help them ascertain whether ammonia concentrations in the Sacramento River and Delta cause beneficial use impairments or contribute to the pelagic organism decline.

Kendall[1], C., M. Young[1], S. Silva[1], A. Parker[2], and D. Dugdale[2]
[1] U.S. Geological Survey
[2] Romberg Tiburon Center, San Francisco State University

Tracing Sources and Biogeochemical Cycling of Ammonium and Nitrate in the Sacramento River and Northern Bay Using Stable Isotope Techniques

The "research framework" developed at the earlier Ammonium Workshop concluded that one of the main research needs was more information on sources, concentrations, fate and transport of nutrients in the Sacramento River, Delta, and Suisun Bay, and suggested that that the multi-isotope approach that our USGS group has been using in the San Joaquin River was one promising means for filling the data gaps. This recent CALFED and USGS-funded study (PIN700) evaluated the usefulness of a multi-isotopic approach for investigating the sources of nutrients and organic matter that contribute to a variety of ecological problems in the San Joaquin River, Delta, and northern San Francisco Bay. This 3-year study piggybacked on several state and federal monitoring programs in the ecosystem that measured various chemical constituents, and we analyzed ~2000 samples from >50 sites for the $\delta^{15}N$ and $\delta^{18}O$ of nitrate; $\delta^{15}N$, $\delta^{13}C$ and C:N of particulate organic matter (POM); $\delta^{13}C$ of dissolved organic and inorganic carbon; and $\delta^{18}O$ and $\delta^{2}H$ of water. Samples were archived for eventual analysis of the $\delta^{15}N$ of ammonium and other isotopic compositions. The study showed that the temporal and spatial variation in isotopic compositions provides unique insights into sources of nitrate, organics, and water that could not have been gained with standard chemical and hydrological measurements. In particular, the $\delta^{15}N$ and $\delta^{18}O$ of nitrate were sensitive indicators of source of the nitrate and nitrification of ammonium, and the $\delta^{15}N$ of POM provided key information on the source of the nutrients and relative contributions of ammonium and nitrate to algal growth.

To assess the potential usefulness of these isotope techniques for determining sources of nutrients and biogeochemical processes in the Sacramento River and downstream areas, the SWC recently provided funding for us to piggyback isotope analyses onto 3 recent transects of the Sacramento River, including ones conducted by the SFSU group in March and April 2009. Approximately 25 samples were collected from each transect of the Sacramento River and northern Bay, and these samples have been analyzed for nutrients, $\delta^{15}N$ of ammonium, as well as nitrate, POM, and water isotopes as listed above. As far as we know, these are the first ever analyses of ammonium stable isotopes in the Sacramento River system, and we are delighted to find that there is at least a 20 permil range of $\delta^{15}N$ values from the different sites, suggesting a range of sources and processes are affecting the isotopic compositions at different locations. Our presentation will provide our preliminary evaluation of the usefulness of these isotope tools for determining sources of ammonium and nitrate and biogeochemical processes in the Sacramento River, using data from both the previous multi-year study and our new transect data.

Guerin, M.
Resource Management Associates

Preliminary Abstract for Fate and Transport Modeling of Ammonia in the Delta Using DSM2

The Delta Simulation Model-2 (DSM2) is a mathematical model for the dynamic simulation of one-dimensional hydrodynamics, water quality and particle tracking in a network of riverine or estuarine channels. It was developed by the California Department of Water Resources to simulate conditions in the Sacramento-San Joaquin Delta. QUAL is the fate and transport module for the simulation of conservative and non-conservative constituents in DSM2. Nutrients are modeled by eleven equations, one each for ammonia, nitrate, nitrite, organic-N, orthophosphate, organic-P, algae, Carbonaceous Biochemical Oxygen Demand (CBOD), dissolved oxygen (DO), salinity and temperature. DSM2 has been previously calibrated for hydrodynamics and salinity in the entire Delta, and for nutrients with a focus on DO along a portion of the San Joaquin River.

In order to investigate hypotheses concerning potential relationships between ammonia dynamics and the Pelagic Organism Decline, QUAL was calibrated to simulate the fate and transport of Delta nutrients and water temperature using historical Delta conditions 1990 - 2008. The modeling focus was on ammonia dynamics and on algal dynamics, with particular consideration for the influence of the two main wastewater sources (treated effluent from Stockton and Sacramento) on ammonia concentration. Because wastewater treatment plant effluent is an important source of nutrients in the Delta, boundary conditions were developed for each of the thirteen effluent outfall locations within the model domain in addition to the standard model boundaries.

Data to inform the main model boundary conditions was available for most of the modeled constituents as irregular time series, typically with a bi-monthly measurement scheme, with the Yolo Bypass/Cache Slough/Liberty Island area being an important exception. The conceptual model for nutrients implemented in QUAL was generally sufficient to simulate nutrient dynamics in the Delta, except for localized algal dynamics. Two invasive clam species – *Corbula* and *Corbicula* – are believed to be an important sink for algae where they are prevalent. QUAL's current formulation for algal dynamics may need to be modified to better simulate the effects of clams.

Model results suggest that the Yolo Bypass/Cache Slough/Liberty Island area may be an important source of nutrients and ammonia under certain flow conditions. Preliminary isotope data and discussions with USGS researchers Kendall and Young also suggest an important role for this area.

QUAL calculations include "volumetric fingerprints" which track the fate of water volumes from each flow boundary. Along with modeled constituent concentrations, these results show that the fate of ammonia is quite complicated along the Sacramento River, particularly downstream of Rio Vista. Although water volumes appear to be consistent along the river, constituent concentrations indicate the path a parcel of water takes as it travels out of the Delta can be much more complicated. Measured and modeled nutrient dynamics in open water areas at Franks Tract, Big Break and in Sherman Lake have unique patterns in comparison with channels. Open water areas are modeled as fully mixed reservoirs in DSM2.

The influence of changes in wastewater volumes and concentrations was investigated with a series of model scenarios manipulating effluent sourced from the Stockton and Sacramento outfalls. Similarly, scenarios were developed to investigate the influence of changes in upstream load on the Sacramento and San Joaquin Rivers.

Van Nieuwenhuyse, E.E.
U.S. Bureau of Reclamation, Division of Environmental Affairs

Nutrient Limitation of Average Summer Chlorophyll Concentration in the Freshwater Delta

This presentation will review the case for nutrient limitation of average summer chlorophyll concentration in the upstream, strictly freshwater reaches of the Sacramento-San Joaquin Delta. The case is based in part on: (i) the response of the Delta to what amounted to a whole-system scale nutrient reduction experiment (the sudden reduction of the Delta's phosphorus supply from the Sacramento regional wastewater treatment plant); (ii) comparisons with the results of similar experiments in the Rhine River in Germany and the Ebro River in Spain; (iii) comparisons with a global phosphorus-chlorophyll relationship for temperate streams; and (iv) the results of the first in a series of planned mesocosm experiments.

Glibert, P.M.
University of Maryland Center for Environmental Science, Horn Point Laboratory

Ammonium – Global Trends, Issues on the East Coast, and Implications for Plankton Dynamics

Not only is nitrogen increasing in the many of the world's coasts and estuaries, but in many regions much of this increase is as ammonium or other "reduced" forms of nitrogen, i.e. urea or dissolved organic nitrogen. The global change in the typical form of nitrogen used as a synthetic fertilizer contributes to this trend, as do rapid population increases and the development of concentrated animal operations. Ammonium is discharged both via runoff as well as from atmospheric deposition. Several estuaries on the US east coast now have ammonium concentrations many-fold higher than in prior decades, and are experiencing more frequent outbreaks of harmful algal blooms. Different algal groups have different preferences for ammonium vs nitrate. Many diatoms have an obligate requirement for nitrate, particularly under cool temperate conditions. Dinoflagellates and cyanobacteria, on the other hand, use ammonium of dissolved organic nitrogen preferentially. These metabolic differences can impact plankton community dynamics.

Vargas, A.
CALFED Science Program

Development of an Ammonia/Ammonium Research Framework for the Delta and Suisun Bay

The California State Water Resources Control Board has identified discharges of ammonia/ammonium [ammonia(um)] from wastewater treatment plants in the Delta watershed as a potential concern related to the recent pelagic organism decline (POD) and has called for further study.

Consistent with its mission, the CALFED Science Program volunteered to host a workshop that would lead to the development of a Research Framework to assess the role of ammonia(um) in the Delta and Suisun Bay ecosystem by a panel of national experts. The principles upon which the Research Framework was to be developed included a transparent and public process and the review of the best available science. CALFED worked with stakeholders to develop workshop where the expert panel would review the best available science and receive input from stakeholders, agency staff, and scientists conducting research in the Delta.

After presenting a draft outline to workshop participants, the panel prepared a draft Research framework. The draft was posted for public comments and the comments submitted to the panel for their consideration. A final Research Framework was produced and posted on CALFED webpage. The Research Framework consisted of the panel's perception of the stakeholder concerns, a conceptual framework and recommendations for research.

The Research Framework identified 12 research topics grouped into 4 main topic areas: 1) modeling, 2) sources and fate and transport, 3) food web interactions, 4) toxicity. Four of the research topics were identified as priority. Three of these priority research recommendations related to developing an integrative model of the major drivers of the Delta ecosystem.

The need for the integrative model was necessary because of the number of competing hypothesis for the phytoplankton production dynamics in the Delta and Suisun Bay including the proliferation of cyanobacteria, reduced springtime diatom blooms, and reduced primary production. Among the hypothesis are inhibition by ammonia(um), voracious grazing by invasive clams, and hydrodynamic alterations (increased residence time). The panel could not rule any of these potential causes and concluded that an integrative model as the best mechanism to integrate the myriad of information. One potential results of the modeling is the ability to predict outcomes from potential management actions; for example, predicting what happens if loading of ammonia(um) is reduced or eliminated.

The fourth priority research recommendation relates to assessing the impacts of cyanobacteria toxins on the Delta ecosystem. Three of the eight remaining non-priority recommendation deal with the proliferation of macrophytes and their impacts on nutrient dynamics and POD habitat. Two other recommendations deal with POD fishes; one with evaluation of ammonia(um) toxicity impacts, and the other with the need for baseline health monitoring. Two other recommendations deal with ammonia inhibition on phytoplankton growth, and other with climate change and potential impacts to cyanobacteria blooms. The Research Framework provides a path forward. More specific plan can be developed from considering the Research Framework and on-going research and priorities.

Irvine, C.
CH2M HILL

A Data and Science Gap Discussion for Delta Ammonia/um

Many questions have been raised about the potential effects of ammonia and ammonium on Delta food-web dynamics, toxicity, and its fate and transport. These questions were discussed on March 10-11th at the CALFED Science Program Ammonia Workshop, and several high priority areas of study were recommended by an Expert Panel (*A Framework for Research Addressing the Role of Ammonia/Ammonium in the Sacramento-San Joaquin Delta and the San Francisco Bay Estuary Ecosystem*, 04/13/09). The ability to answer many additional questions about potential ammonia effects with the existing data are further being summarized by members of the Ammonia Workshop Planning Committee and POD-Contaminant Work Team (POD-CWT) in a data and science gap analysis (DaSGA). This DaSGA is a living document listing questions posed about potential ammonia effects in the Delta, the current state of ammonia research in the Delta, how well these data answer the questions, and the relative priority of future research needs. Based on a discussion with the audience we will try to determine a scientific consensus on the relative prioritization (e.g., high, medium, and low) for further studies needed to answer the most important questions about ammonia fate and transport, food-web interactions, and toxicity in the Delta. The DaSGA fulfills one of the purposes of the POD-CWT strategy (January, 2009), by identifying and prioritizing ammonia/ammonium related investigations. This will assist investigators in developing research proposals to answer critical data gaps and help funding agencies focus limited resources where they are needed most.